QUATERNARY GEOLOGIC MAP OF THE SUDBURY 4° × 6° QUADRANGLE, UNITED STATES AND CANADA

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QUATERNARY GEOLOGIC ATLAS OF THE UNITED STATES

GLACIAL DEPOSITS LAKE DEPOSITS

CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

Im LAKE CLAY AND SILT UNDER LAKE HURON—Brownish-gray, gray, or grayish-black calcareous clay, silty clay, and silt. Typically clay and silty clay in deeper parts of basins, silt closer to basin margins. Soft, fluid, compressible. Locally porous; may contain gas bubbles. Faintly laminated to massive. In places contains mollusc tests, wood chips, and plant debris. Deep-water facies of modern lake deposits. Commonly overlain by lake sand (Is) 1-6 cm thick. Thickness 1-6 m, locally more

Is LAKE SAND AND GRAVEL UNDER LAKE HURON—Brown, brownishgray, or gray, calcareous silty fine sand, fine to coarse sand, and gravel. Poorly to well sorted; locally stratified. Mollusc tests and fragments common. Shore and nearshore facies of modern lake deposits. Includes local accumulations of boulders and cobbles or coarse lag gravel. Also includes areas of bedrock and thin till over bedrock. Thickness 1-5 m, rarely 10 m

> DUNE SAND—Pale-yellow, yellowish-brown, and pale-brown, calcareous or noncalcareous, well-sorted, finely laminated or crossbedded, fine to medium sand and local coarse silt. Mapped only in Michigan, where sand occurs as massive dune ridges parallel to present shore of Lake Huron and as longitudinal and parabolic dunes on former lake beds, on outwash plains, and on till downwind from outwash plains; included in other map units (gs, gg, ks, kg, gkl, lsa, and till) in Ontario and Quebec. Includes some windblown sheet sand and loess. Dunes generally stable; locally active where vegetation has been removed. Some isolated areas of dunes in Ontario are shown by symbol.

HOLOCENE AND LATE WISCONSIN SANDY TILL-Brownish-yellow, grayish-yellow, yellowish-brown, reddish-

brown, olive-brown, grayish-brown, brown, olive, reddish-gray, yellowish-gray, brownish-gray, olive-gray, bluish-gray, gray, or mottled sand, loamy sand, and sandy loam; locally loam, silt loam, sandy clay loam, or silty clay. Colors and textures reflect composition of loca! igneous and metamorphic bedrock. Generally noncalcareous or very weakly calcareous. Typically weathered throughout because of coarse texture, thinness of deposit, and low permeability of underlying bedrock. Nonsorted or very poorly sorted; nonstratified or very poorly stratified. Stringers, lenses, interbeds, and clasts of contorted silt, sand, and gravel common, particularly near base. In many areas, upper 1-2 m of map unit is reworked till comprising subaqueous and subaerial debris-flow deposits, sediment-flow deposits, and flowtill. Upper 1-2 m of till typically is very sandy; loose to moderately compact; gritty, stony; crudely stratified; thin sorted and deformed silt beds common; friable; platy structure common; clasts dominantly cobbles and boulders; boulder and cobble litters common on surface. Till below is nonstratified, commonly with subhorizontal parting; typically either weakly cohesive and slightly fissile till or massive, dense, hard, and jointed till with iron oxide stains on joint surfaces; generally pebbly; locally gravelly, stony, or rubbly; cobbles and boulders common to very abundant. Clasts in most areas are almost exclusively igneous and metamorphic rocks; erratic limestone pebbles and small cobbles present locally. In places resembles outwash or ice-contact sand and gravel (gg, kg), but lacks pronounced stratification. Occurs chiefly as ground moraine, locally as drumlins, end moraine, or hummocky stagnation moraine. Includes areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (Ica, Isa, Iu), alluvium (al), and bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs) Ground moraine and end moraine-Some segments of end moraine

shown by symbol. Thickness 1-5 m, locally 30 m Discontinuous sandy till-Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In many areas bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes and map unit is almost entirely bedrock with isolated remnants of till (ts) and lake clay, silt, sand, and gravel (Ica, Isa, Iu). Thickness less than 2 m Ground moraine under Lake Huron (late Wisconsin only)-Includes areas of bedrock and local accumulations of cobbles and boulders or

lag gravel. Thickness 1-3 m AME MORAINE DEPOSIT-Pale-yellow, yellowish-brown, reddishbrown, brown, brownish-gray, gray, or mottled, noncalcareous or weakly calcareous ice-contact sand and gravel similar to unit kg, occurring as aligned, massive, linear or arcuate ridges or as aligned belts of undulating or hummocky topography with local ridges. In places interbedded with or contains lenses of till or flowtill; locally overlies or is intertongued with lake clay, silt, sand, and gravel (Ica, Isa, Iu). Sorting, stratification, and textures vary vertically and laterally. Faults, folds, and slump and collapse structures common. Clasts subangular to rounded pebbles, cobbles, and boulders of igneous and metamorphic rocks. Northernmost deposits in northwest quarter of quadrangle were overridden by ice during a minor glacial readvance; discontinuous till and flowtill locally is draped over those deposits. Locally overlain by peat (hp). Thickness 3-30 m

ICE-CONTACT SAND AND GRAVEL—Pale-yellow, yellowish-brown,

reddish-brown, olive-brown, grayish-brown, brown, brownish-gray, gray, or mottled sand and gravel with minor silt. Textures vary laterally and vertically, ranging from fine sand with minor silt and scattered pebbles to cobble and boulder gravel. Calcareous or noncalcareous, reflecting composition of source materials. Poorly to well sorted; poorly to well stratified. Crudely bedded to well bedded; beds discontinuous laterally. Locally interbedded with or contains masses of clay, silt, flowtill, or till; in places, mantled by a thin veneer of till or flowtill. Gravel locally cemented by secondary calcium carbonate where clasts include limestone or dolomite. Faults, folds, slump, and collapse structures common. Clasts subangular to rounded pebbles, cobbles, boulders, and blocks. Clast composition similar to that of other stratified materials and till in same area. Surfaces hummocky to knobby; commonly pitted with ice-block depressions; surface litter of cobbles and boulders common. In some areas, deposits subsequently were modified and reworked by waves and currents in lakes and upper part of map unit is lake sand and gravel (Isa). Occurs in kames, kame terraces, eskers, and ice-fracture fillings; some eskers are indicated by symbol. Includes ice-contact sand (ks) where units kg and ks have not been distinguished and some kame moraine deposits (ke), kame delta deposits, lake delta deposits, and subaqueous fan deposits. Also includes areas of outwash sand and gravel (gs, gg), lake clay, silt, sand, and gravel (Ica, Isa, Iu), alluvium (al), till, and bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs). Thickness 1-30 m, locally

OUTWASH SAND AND GRAVEL-Pale-yellow, yellowish-brown, reddishbrown, brown, gray, or mottled sand and gravel. Calcareous or noncalcareous, reflecting composition of source materials. In Michigan, typically fine to coarse sand alternating with beds of granule to cobble gravel; in Ontario south of north shore of Lake Simcoe, generally pebble or cobble gravel with lenses and interbeds of clay, silt, and sand; farther north in Ontario and Quebec, generally sand and pebble, cobble, or boulder gravel. Textures generally coarsen with depth and vary laterally. Poorly to well sorted; crudely to well stratified. Bedding varies from (1) horizontal beds of well sorted sand, (2) pebbly sand with ripple-drift, planar, or trough crossbeds, or (3) interbedded pebbly sand and cobble or boulder gravel to (4) pebble, cobble, or boulder gravel. Cobbles and boulders abundant where outwash deposits head near end moraine, kame moraine, or ice-contact deposits. Clasts subrounded to very well rounded; size of largest clasts typically decreases downstream in valley train deposits. Clasts lithology varies with lithologies of local bedrock and till; chiefly dolomite, limestone, sandstone, and shale in Michigan and in Ontario south of north shore of Lake Simcoe and chiefly igneous and metamorphic rocks farther north in Ontario and Quebec. Clasts locally intensely stained by iron oxides; gravel locally cemented by secondary calcium carbonate where clasts include limestone or dolomite. In many areas, deposits were modified and reworked by waves and currents in lakes and outwash sand and gravel is overlain by unmapped lake sand and gravel (Isa). Occurs in valley trains, outwash plains, fans and aprons, terrace remnants, and delta topset beds and as fills in meltwater channels. Surfaces typically smooth to undulating; locally pitted with ice-block depressions. Includes outwash sand (gs) where units gs and gg have not been distinguished. Includes areas of till, ice-contact sand and gravel (ks, kg), kame moraine deposits (ke), lake delta deposits, lake clay, silt, sand, and gravel (Ica, Isa, Iu), alluvium (al), and bedrock. Locally overlain by dune sand (ed), peat (hp), swamp deposits (hs), subaqueous or

sand with scattered pebbles and stringers and lenses of clay and

organic material; lower part typically pebbly sand or gravel and sand;

subaerial debris-flow deposits, sediment-flow deposits, or flowtill. Thickness 1-30 m, locally more than 60 m than 40 m ALLUVIUM—Yellowish-brown, brown, brownish-gray, gray, or mottled calcareous silt, sand, and gravel. Moderately to well sorted. Poorly to well stratified; bedding generally horizontal; cut-and-fill crossbeds common. Textures vary laterally and vertically; contrasting textures may be intertongued or interbedded. Upper part typically silt and fine

local cobble or boulder gravel. Clast lithologies reflect compositions of bedrock and other surface materials in same area. Overbank, stream channel, and fan deposit; underlies flood plains, low stream terraces, and alluvial fans. Mapped only in part of southern Ontario; included in other map units elsewhere. Includes areas of till, outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa, Iu), and bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs). Thickness of overbank and channel alluvium 1-4 m, rarely more than 6 m; thickness of fan alluvium locally more than 10 m

Ic LAKE SILT AND CLAY UNDER LAKE HURON—Pale-brown, reddishbrown, reddish-gray, brownish-gray, or gray, very calcareous silty clay and clay. Generally well sorted; poorly to well stratified. Massive to laminated; locally varved. Ice-rafted clasts common; organic detritus absent. Much more compact than unit Im. Offshore and deep-water facies of deposits of former glacial and postglacial lakes. Commonly overlain by well-sorted silt or sand (Is) 2-28 cm thick. Thickness 1-5 m, locally 10-15 m

loa LAKE SILT AND CLAY-Pink, red, pale-yellow, yellowish-brown, reddish-brown, grayish-brown, brown, grayish-green, pinkish-gray, reddish-gray, brownish-gray, bluish-gray, gray, or mottled silt and clay; locally silt, silty sand, and very fine sand. Calcareous or noncalcareous, reflecting composition of source materials. Well sorted; stratified. Well bedded to massive; soft to very firm. Sticky and plastic where damp; weak to strong blocky structure where dry; ocally jointed or fractured. Commonly laminated; locally varved. Icerafted clasts common in lower part in some regions. In places, strongly contorted with load structures; locally folded and faulted. In some areas, interbedded with sand or fine gravel or with till or flowtill. Mollusc and gastropod tests and secondary calcium carbonate concretions common locally. Sinkholes common where deposit is thin over limestone or dolomite. Gullies common adjacent to major streams. Offshore deposit of former lakes. Includes areas of collapsed or terraced lake silt and clay. Also includes areas of outwash and icecontact sand and gravel (gs, gg, ks, kg), kame moraine deposits (ke), lake sand and gravel (Isa), alluvium (al), till, and bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs). Thickness 1-10 m, locally more than 30 m

DISCONTINUOUS LAKE SILT AND CLAY—Thin, discontinuous clay and silt (Ica) over bedrock. Most of area is wave- or current-washed bedrock or wave- or current-washed till with isolated patches of silt

and clay. Thickness generally less than 1 m Isa LAKE SAND AND GRAVEL—Pale-yellow, brownish-yellow, reddishbrown, yellowish-brown, grayish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled fine-to-coarse sand and silty sand with layers of medium gravel or lenses of silt and pebble gravel; locally pebble or cobble gravel. Calcareous or noncalcareous, reflecting composition of source materials. Generally well sorted; well stratified. Commonly crossbedded or parallel bedded; local lenticular or tabular foreset beds. In places, chiefly rhythmically laminated sand and silt; locally massive. Grain size typically coarsens upward in thick deposits. In places, interbedded or intercalated with lake silt and clay (Ica), till, or flowtill. Locally deformed; load and dewatering structures common. Friable; very weakly developed coarse blocky structure common. Locally contains wood fragments, plant debris, and tests of molluscs and gastropods. Clasts generally well rounded; clast composition reflects composition of other surficial materials that were transported by waves and currents. Sinkholes common locally where deposit is thin over limestone or dolomite. Nearshore, strand, deltaic, and shallow-water deposits of former lakes, including deposits of beach ridges, offshore bars, spits, and local delta or subaqueous underflow fan deposits. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), kame moraine deposits (ke), lake silt and clay (Ica), alluvium (all), till, and bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs). Thickness 1-10 m,

locally 30 m Isr DISCONTINUOUS LAKE SAND AND GRAVEL-Thin, discontinuous lake sand and gravel (Isa) over bedrock. Includes areas of thin, discontinuous lake silt and clay (Ica). Most of mapped area is wave- or current-washed bedrock or wave- or current-washed till with isolated patches of sand and gravel. Thickness generally less than 1 m LAKE CLAY, SILT, SAND, AND GRAVEL-Complex deposit of ndifferentiated lake silt and clay (Ica) and lake sand and gravel (Isa). Thickness 1–10 m, locally more than 30 m

discontinuous, undifferentiated lake clay, silt, sand, and gravel (Iu) over bedrock. Most of mapped area is wave- or current-washed bedrock or wave- or current-washed till with isolated patches of clay, silt, sand, and gravel. Thickness generally less than 1 m hp PEAT AND MUCK-Black or dark-brown fibrous undecomposed peat overlying partly to well decomposed fibrous peat and organic clay and silt containing comminuted plant material and organic residues. Occurs on former lake beds, as bogs in ice-block depressions, and in other shallow depressions and poorly drained areas. Mapped only where extensive. Included in swamp deposits (hs) where peat and swamp deposits have not been distinguished. Thickness 1-3 m,

ISCONTINUOUS LAKE CLAY, SILT, SAND, AND GRAVEL-Thin,

hs SWAMP DEPOSIT - Dark-brown or black muck, mucky peat, and organic residues mixed with fine-grained mineral sediment. Occurs on former lake beds, as bogs in ice-block depressions, and in other shallow depressions and poorly drained areas. Includes peat (hp) where peat and swamp deposits have not been distinguished. Mapped only where extensive. Thickness 1-5 m, rarely 15 m

LATE WISCONSIN Tills in Michigan

CLAYEY TILL-Yellowish-brown, reddish-brown, brownish-gray, or mottled calcareous clay, silty clay, silty clay loam, and clay loam. Nonsorted or very poorly sorted; nonstratified. Locally interbedded with sand and gravel. Pebbles infrequent; very few cobbles and boulders. Pebbles and cobbles chiefly subangular to well rounded sandstone, limestone, dolomite, and shale; large boulders dominantly erratic igneous and metamorphic rocks. Includes areas of loamy till (tl), sandy loamy till (td), outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). In places overlain by dune sand (ed), peat (hp), or swamp deposits (hs) Ground moraine-Thickness 2-20 m, locally 30 m

End moraine-Broad, low ridges or linear belts of hummocky till with andrained ice-block depressions. Thickness 10-30 m LOAMY TILL-Yellowish-brown, reddish-brown, brown, brownish-gray, bluish-gray, gray or mottled calcareous loam and silt loam; minor silty clay loam and clay loam. Nonsorted or poorly sorted; nonstratified. Compact; horizontal platy structure common. Generally moderately pebbly; locally cobbly or bouldery. Gravel lenses or interbeds common locally, particularly in end moraine. Pebbles and cobbles chiefly subangular to well rounded sandstone, limestone, dolomite, and shale; large boulders dominantly erratic igneous and metamorphic rocks. Includes areas of clayey till (tc), sandy loamy till (td), outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand,

local accumulations of cobbles and boulders or lag gravel. Thickness

Nonsorted to poorly sorted; nonstratified. Commonly contains lenses resembles outwash sand and gravel (gg) owing to abundance of wellrounded clasts. Deposits are nonstratified, however, and commonly nclude lenses of clayey or silty till and flowtill. Includes areas of clayey

undrained ice-block depressions. Thickness 10-30 m, locally more Discontinuous sandy loam till-Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In many areas bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes;

Tills in Ontario CLAYEY TILL (St. Joseph Till) - Yellowish-brown, brown, brownish-gray, gray, or mottled calcareous silty clay, clayey silt, silty clay loam, and silt loam. Clay content generally increases southward. Nonsorted; nonstratified. Compact to very compact; massive to blocky structure. Pronounced columnar jointing; clay skins and secondary calcium carbonate common on joint and fracture surfaces. Low plasticity. Matrix chiefly incorporated lake silt and clay; locally intercalated or interbedded with silt and clay or contains clasts of lake silt and clay. In places occurs primarily as deformation till. Matrix averages 45 percent carbonate, dominantly dolomite. Locally gritty where derived from shale. Clasts infrequent. Pebbles dominantly limestone and dolomite; some sandstone, shale, and erratic igneous and metamorphic rocks. Large boulders chiefly erratic metasedimentary and metavolcanic rocks. Tillite and jasper conglomerate erratics common locally. Includes some outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by thin loess, dune sand (ed), peat (hp), or swamp

Ground moraine and end moraine—Some segments of end moraine shown by symbol. Thickness 2-5 m, locally more than 30 m Ground moraine under Lake Huron-Includes areas of bedrock and local accumulations of boulders and cobbles or lag gravel. Thickness

CLAYEY TILL (Kettleby Till and unnamed till)-Pale-brown, brown, brownish-gray, gray, or mottled calcareous silty clay, clayey silt, silty clay loam, and silt loam. Nonsorted; nonstratified. Commonly intercalated or interbedded with lake silt and clay or contains clasts of silt and clay. In places, composed entirely of incorporated lake silt and clay. Locally sheared or deformed. Moderately compact; massive to blocky structure. Secondary calcium carbonate concretions common locally. Clast free or with scattered pebbles. Pebbles domimantly limestone, dolomite, siltstone, shale, and sandstone; minor erratic igneous and metamorphic rocks. Cobbles and boulders rare; dominantly erratic igneous and metamorphic rocks. Occurs chiefly as discontinuous ground moraine veneer on older loamy or sandy loamy till. Includes areas of older till, outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by thin loess, dune sand (ed), peat (hp), or swamp deposits (hs). Thickness 0.5-5 m, locally 12 m tkq LOAMY TILL—Yellowish-brown, brown, gray, or mottled calcareous silt very compact; blocky structure. Matrix chiefly incorporated lake

sediment; locally gritty. Clast free or with scattered pebbles. Pebbles chiefly limestone, dolomite, siltstone, shale, and sandstone; minor erratic igneous and metamorphic rocks. Occurs chiefly as discontinuous ground moraine veneer on older loamy or sandy loamy till; in places forms end moraine, shown by symbol. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), alluvium (al), and older loamy or sandy loamy till. Locally overlain by peat (hp), swamp deposits (hs), dune sand (ed), or thin loess. Thickness 2-5 m, locally 30 m LOAMY TILL (Halton Till) - Yellowish-brown, light-olive-brown, gravishbrown, gray, or mottled calcareous loam, silt loam, sandy loam, and clay loam; locally silty clay. Nonsorted; nonstratified. Commonly intertongued or interbedded with lake silt and clay; may contain local

flowtill units near lower and upper contacts. Low plasticity. Matrix carbonate content varies, chiefly calcite. Scattered pebbles; some cobbles and boulders. Clasts chiefly limestone and shale; minor erratic igneous and metamorphic rocks. Occurs chiefly as ground moraine. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs). Thickness 1-6 m, locally 30 m LOAMY TILL (Rannoch Till)—Yellowish-brown, reddish-brown, brown, gray, or mottled calcareous silt loam and silty clay loam. Nonsorted; nonstratified. Low plasticity. Blocky structure common; secondary carbonate on fracture surfaces. Matrix carbonate dominantly dolomite.

Clasts infrequent, dominantly pebbles of dolomite, limestone, chert, sandstone, siltstone, and shale; minor erratic igneous and metamorphic rocks. Occurs as ground moraine. Includes small areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs). Thickness 2-6 m LOAMY TILL (Elma Till) - Yellowish-brown, reddish-brown, brown, gray,

or mottled very calcareous silt loam, loam, and silty clay loam. Nonsorted; nonstratified; generally lacks inclusions of clay, silt, sand, and gravel. Fissile; low plasticity or nonplastic. Matrix carbonate chiefly dolomite; matrix locally gritty. Sparingly pebbly to pebbly. Clasts dominantly dolomite and limestone; some sandstone, siltstone, shale, and chert; minor erratic igneous and metamorphic rocks. Locally very loose and bouldery, with blocks of angular dolomite. Occurs chiefly as ground moraine, locally as drumlins; some segments of end moraine shown by symbol. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by peat (hp), swamp deposits (hs), or a thin, discontinuous veneer of younger till. Thickness 1-6 m, locally 15 m

LOAMY TILL (Tavistock Till)-Reddish-brown, light-brown, brown, gray, or mottled very calcareous silty clay loam, silt loam, clay loam, and silty clay. Nonsorted; nonstratified. Local lenses or thin interbeds of lake silt and clay. Massive to blocky structure; very stiff, low plasticity. Matrix carbonate chiefly dolomite. Locally gritty. Clasts rare, chiefly dolomite pebbles; some limestone, sandstone, siltstone, shale; minor erratic igneous and metamorphic rocks. Occurs chiefly as low-relief ground moraine that locally is fluted, or as drumlins; locally occurs as veneer of ground moraine on older end moraine; some segments of end moraine shown by symbol. Includes areas of outwash and icecontact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by peat (hp), swamp deposits (hs), or a thin, discontinuous veneer of younger till. Thickness 2-12 m

LOAMY TILL (Catfish Creek Till)-Yellowish-brown, brown, brownishgray, gray, or mottled very calcareous loam, silt loam, and sandy loam. Nonsorted; nonstratified. Massive, compact; low plasticity or nonplastic. Matrix carbonate dominantly dolomite. Moderately pebbly to pebbly; cobbles and boulders common. Clasts chiefly dolomite; some limestone, sandstone, siltstone, shale, chert; minor erratic igneous and metamorphic rocks. Occurs as ground moraine and end moraine. Includes small areas of outwash and ice-contact sand and gravel (gs. gg, ks, kg), lake clay, silt, sand and gravel (Ica, Isa), and alluvium (all). Locally overlain by peat (hp) or swamp deposits (hs). Thickness 2-15 m

SANDY LOAMY TILL (Newmarket Till and unnamed till)-Yellowishbrown, brown, brownish-gray, gray, or mottled calcareous sandy loam and loam; some silt loam, silty clay loam, and clay loam. Grades northward into sandy till (ts). Nonsorted; nonstratified or poorly stratified. Commonly contains abundant lenses of sand and gravel. Friable; fissile where dry. Locally gritty. Nonplastic; soft to very stiff; typically very compact. Blocky structure where more clayey. Either calcite or dolomite dominant in matrix. Typically moderately pebbly or pebbly. Pebbles and cobbles chiefly limestone and siltstone or dolomite and siltstone, reflecting composition of local bedrock; chiefly erratic igneous and metamorphic rocks. Occurs chiefly as ground moraine, locally as drumlins or drumlinoid hills. In areas where surface was modified by waves and currents in lakes, includes discontinuous patches of lake clay, silt, sand, and gravel (Ica, Isa) over till. Also includes areas of older till, outwash and ice-contact sand and gravel (gs, gg, ks, kg), kame moraine deposits (ke), and alluvium (al). ocally overlain by dune sand (ed), peat (hp), or swamp deposits (hs)

Thickness 0.5-6 m, locally 12 m Ground moraine under Lake Huron-Includes areas of bedrock and local accumulations of cobbles and boulders or lag gravel. Thickness

Discontinuous sandy loamy till-Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In many areas bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes and map unit is almost entirely bedrock with isolated remnants of till (teb) and lake clay, silt, sand, and gravel (Ica, Isa). Thickness less than

or mottled calcareous coarse sand, loamy sand, or sandy loam; locally reddish brown or reddish gray silty clay where derived from red shale and siltstone. Poorly sorted; nonstratified. In places intertongued or interbedded with poorly sorted gravel. Typically compact; locally loose. Extremely stony and bouldery; clasts chiefly angular and subangular pebbles, cobbles, boulders, and blocks of limestone. Commonly fewer than 2 percent of clasts are igneous and metamorphic rocks from Canadian Shield to north; crystalline boulders conspicuous locally. Typically very hummocky; relief of irregular mounds generally less than 6 m, locally 15 m. Includes some outwash

overlain by peat (hp) or swamp deposits (hs). Map unit is "Dummer moraine" of Deane (1950), Gravenor (1957), and Chapman and Putnam (1973, 1984); however, deposit was not formed as an end moraine (Shulmeister, 1989). Thickness 1-4 m, locally 30 m E-CONTACT SAND-Pale-yellow, yellowish-brown, reddish-brown, brown, grayish-brown, gray, or mottled calcareous fine to coarse sand with minor silt and scattered pebbles. Poorly to moderately sorted;

OUTWASH SAND-Pale-yellow, yellowish-brown, reddish-brown, brown,

gray, or mottled calcareous fine to coarse pebbly sand and minor silt.

Well sorted; crudely to well stratified. Typically horizontally bedded;

local beds or lenses of granule or pebble gravel and lenses of silt.

Clasts well rounded; clast composition reflects lithology of bedrock

and composition of till in same area. Occurs chiefly as sheet deposits

beneath terraces and outwash plains and as channel fills. Surfaces

smooth or pitted with ice-block depressions. In some areas, outwash

sand subsequently was modified and reworked by waves and currents

in lakes and upper part of map unit is discontinuous lake sand and

gravel (Isa). Distinguished from outwash sand and gravel (gg) only in

Ontario south of north shore of Lake Simcoe; included in unit gg

elsewhere. Includes some outwash and ice-contact sand and gravel

(gg, ks, kg), lake clay, silt, sand, and gravel (Ica, Isa), alluvium (al), and

bedrock. Locally overlain by dune sand (ed), peat (hp), or swamp

outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay,

silt, sand, and gravel (Ica, Isa), and till (tka, teb) in southeast corner of

quadrangle. Core of deposit typically is outwash sand and gravel (gs,

gg) with clasts as large as 20 cm in diameter; upper part typically is

sand and coarse silt. Ice-contact deposits (ks, kg), on north and south

flanks of area mapped, typically are partly or entirely buried by

outwash deposits (gs, gg) and lake deposits (Ica, Isa). Lake silt and

varved clay and silt as thick as 6 m are common on north flank of area

mapped; thinner lake sediments locally on crest. Topography on crest

typically hummocky; ice-block depressions common locally. Topog-

raphy on flanks typically rolling, with isolated hummocks or mounds.

Outwash, ice-contact, and lake deposits were overridden by read-

vancing ice margins on north and south flanks of area mapped; till on

flanks is more clayey than typical textures of those units (tka, teb)

elsewhere, owing to incorporation of proglacial lake clay and silt. Map

unit is "Oak Ridges moraine" of older literature; however it is not an

end moraine (Gwyn and Cowan, 1978; Duckworth, 1979; Chapman,

1985). Sediments were deposited on a topographic high, in an inter-

lobate position, during separation of late Wisconsin ice lobe margins

in southern Ontario. Includes inset alluvium (al). Commonly overlain

by dune sand (ed) in fields of lunate dunes, eolian sheet sand and

loess 1-3 m thick, and local peat (hp) and swamp deposits (hs).

Thickness 10-30 m, locally more than 90 m

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Thickness 2-30 m

deposits (hs). Thickness 1-6 m

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SUDBURY 4° × 6° QUADRANGLE

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Materials are distinguished on the basis of lithology or composition, texture or particle size, and other physical, chemical, and engineering characteristics. It is not a map of soils recognized and classified in pedology or agronomy. Rather, it is a generalized map of soils as recognized in engineering geology, or of substrata or parent materials in which pedologic and agronomic soils are formed. As a materials map it serves as a base from which a variety of maps for use in planning engineering, land use, or land management projects NOTE 2: A major regional glacial readvance in the Lake Superior basin west of the northwest quarter of this quadrangle (the more than 60 m Marquette advance) culminated approximately 10,000 yr B.P., synchronous with the arbitrarily defined Pleistocene-Holocene boundary of Hopkins (1975). Deposits of the advance in northern Michigan, in the adjacent Lake Superior 4°×6° quadrangle (Farrand and others, 1984), were not distinguished as map units or by a glacial readvance symbol. Deposits of the Marquette advance in Michigan, represented by an advance limit and two recessional ice margin positions, subsequently were traced eastward to Whitefish Bay in the southeastern end of Lake Superior (Drexler and others, 1983; Farrand and Drexler, 1985). Three east-west trending belts of kame moraine deposits between lat 46°30' and 47° N. in this uadrangle, traced from Whitefish Bau to Capreol, Ont., bu Boissones (1965, 1968), are aligned with the trends of the three Marquette ice margin positions in Michigan. It is possible that those belts of kame moraine deposits are products of the Marquette glacial readvance. If so, all till and other sediments deposited prior to formation of the southernmost belt of kame moraine are Pleistocene (late Wisconsin) in age and all till and other sediments that were deposited during and after recession of the ice margin from the readvance limit are Holocene in age. Boissonneau, A.N., 1965, Surficial geology, Algoma, Sudbury, miskaming, and Nipissing: Ontario Department of Lands and Forests Map S465, scale 1:506,880. _____1968, Glacial history of northeastern Ontario, II; The limiskaming-Algoma area: Canadian Journal of Earth Sciences, v. 5, p. 97-109. Drexler, C.W., Farrand, W.R., and Hughes, J.D., 1983, Correlation of glacial lakes in the Superior basin with eastward discharge events from Lake Agassiz, in Teller, J.T., and Clayton, Lee, eds., Glacial Lake Agassiz: Geological Association of Canada Special Paper 26, p. 309-329. Farrand, W.R., and Drexler, C.W., 1985, Late Wisconsinan and Holocene history of the Lake Superior basin, in Karrow, P.F., and Calkin, P.E. eds., Quaternary evolution of the Great Lakes:

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LIST OF MAP UNITS

LAKE CLAY AND SILT UNDER LAKE HURON

Ground moraine under Lake Huron (late Wisconsin

Is LAKE SAND AND GRAVEL UNDER LAKE HURON

HOLOCENE AND LATE WISCONSIN

Ground moraine and end moraine

Discontinuous sandy till

KAME MORAINE DEPOSIT

kg ICE-CONTACT SAND AND GRAVEL

LAKE SAND AND GRAVEL

OUTWASH SAND AND GRAVEL

LAKE SILT AND CLAY UNDER LAKE HURON

DISCONTINUOUS LAKE SILT AND CLAY

LAKE CLAY, SILT, SAND, AND GRAVEL

LATE WISCONSIN

Tills in Michigan

Ground moraine under Lake Huron

Ground moraine under Lake Huron

Tills in Ontario

Ground moraine and end moraine

Ground moraine under Lake Huron

CLAYEY TILL (Kettleby Till and unnamed till)

Ground moraine and end moraine

Ground moraine under Lake Huron

DIRECTION OF ICE MOVEMENT INDICATED BY

ICE MARGIN-Solid where known, dashed

where inferred; ticks on side of advance. Limit of

Port Huron phase advance in Michigan; limits of

younger late Wisconsin and Holocene advances

and stillstands in Ontario in west half of quad-

KAME MORAINE DEPOSIT-Mapped only in

STRIATED OR GROOVED BEDROCK

ICE-MOLDED LANDFORM—Drumlin, rock drumlin,

LIMIT OF GLACIAL ADVANCE OR STILLSTAND OF

..... CREST OF UNMAPPED TILL END MORAINE OR

NOTE 1: This map is a product of collaboration of the Ontario

Geological Survey, the University of Michigan, and the U.S.

Geological Survey and is designed for both scientific and practical

purposes. It was prepared in two stages. First, separate maps and

map explanations were prepared by the compilers. Second, the

maps were combined, integrated, and supplemented by the editor.

Map unit symbols were revised to a uniform system of classification,

and map unit descriptions were prepared by the editor from

information received from the compilers and from additional

sources. Diagrams accompanying the map were prepared by the

surficial deposits on the basis of lithology or composition, texture or

particle size, structure, genesis, stratigraphic relationships, engineering

geologic properties, and relative age, as shown on the correlation

diagram and indicated in the descriptions of map units. Deposits of

some constructional geomorphic features, such as end moraines,

are distinguished as map units. Deposits of erosional landforms,

such as stream terraces, are not distinguished, although alluvial

deposits that are mapped may be terraced. As a Quaternary

geologic map it serves as a base from which a variety of maps

For practical purposes, the map is a surficial materials map.

relating Quaternary geologic history can be derived.

For scientific purposes, the map differentiates Quaternary

Ontario and Quebec

Discontinuous sandy loamy till

Discontinuous sandy loamy till

CLAYEY TILL (St. Joseph Till)

DISCONTINUOUS LAKE SAND AND GRAVEL

DISCONTINUOUS LAKE CLAY, SILT, SAND, AND

ed DUNE SAND

SANDY TILL

ALLUVIUM

hp PEAT AND MUCK

hs SWAMP DEPOSIT

Ground moraine

Ground moraine

SANDY LOAMY TILI

Ground moraine

End moraine

LOAMY TILL

End moraine

End moraine

LOAMY TILL

tsa SANDY TILL

ks ICE-CONTACT SAND

CLACIAL LAKE SPILLWAY

GLACIAL LAKE DELTA

flute, or groove

98 OUTWASH SAND

CONTACT

^ ^ ^ ^ DUNE FIELD

ka LOAMY TILL (Halton Till)

tkn LOAMY TILL (Elma Till)

g LOAMY TILL (Rannoch Till)

LOAMY TILL (Tavistock Till)

ki LOAMY TILL (Catfish Creek Till)

gkl OUTWASH SAND AND GRAVEL

Ica LAKE SILT AND CLAY

and gravel (Ica, Isa), and alluvium (al). Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs) Ground moraine-Thickness 2-20 m, rarely 30 m Ground moraine under Lake Huron-Includes areas of bedrock and End moraine—Broad, low ridges or linear belts of hummocky till with undrained ice-block depressions. Thickness 8-30 m SANDY LOAMY TILL-Yellowish-brown, reddish-brown, brown, gray, or mottled calcareous sandy clay loam, sandy loam, and loamy sand. subangular to well rounded limestone, dolomite, shale, and sandstone;

of clay or silt. Pebbly to bouldery. Pebbles and cobbles dominantly large boulders chiefly erratic igneous and metamorphic rocks. Locally till (tc), loamy till (tl), outwash and ice-contact sand and gravel (gg. kg), lake clay, silt, sand, and gravel (Ica, Isa), and alluvium (al). Locally overlain by dune sand (ed), peat (hp), or swamp deposits (hs) Ground moraine-Thickness 2-20 m, locally 30 m

Ground moraine under Lake Huron-Includes areas of bedrock and local accumulations of boulders and cobbles or lag gravel. Thickness End moraine-Broad, low ridges or linear belts of hummucky till with

map unit is almost entirely bedrock with isolated remnants of sandy

loamy till (td) and lake clay, silt, sand, and gravel (Ica, Isa). Thickness

Ground moraine and end moraine-End moraine shown by symbol.

SANDY TILL-Brownish-yellow, yellowish-brown, brownish-gray, gray, and ice-contact sand and gravel (gg, kg) and alluvium (al). Locally